Cardiac Problem Solving: Imaging the Coronary Arteries in 2006 -

CT vs MRA: A Radiologist's Perspective

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Introduction

The small size and fast motion of the coronary arteries puts any non-invasive diagnostic imaging modality to the test. Both Magnetic Resonance Imaging (MRI) and Multislice Computed Tomography (MSCT) are being tested to prove themselves to be capable of depicting the coronary arteries with a sufficiently high temporal and spatial resolution for a constant and adequate image quality (2). Coronary MRI is going through constant developments, including new acquisition techniques such as parallel imaging (3), higher field strengths (4), intravascular contrast agents (5), free-breathing and refined navigator techniques (6), whole-heart three-dimensional (3D) applications (7), and others. On the other hand, MSCT is making considerable technical progress, with the innovation cycles between scanner generations becoming shorter and shorter. While the first 4-slice CT system was introduced in 1998, and 16-slice followed in 2002, already two years later, in 2004, the 64-slice generation was at hand (8). And just recently, the first dual-source CT (DSCT) has been announced, drastically improving temporal resolution, being introduced to clinical practice in early 2006. Development of both MSCT and MRI is ongoing, but although no direct, intra-individual comparisons have been performed yet, MRI

seems at this moment outperformed by 64-slice MSCT, with the DSCT results still to come.

Coronary Multislice Computed Tomography Angiography

The ongoing development of MSCT, introducing 16SCT in 2002 and 64SCT in 2004, has established the dominant role of CT in today's non-invasive coronary artery imaging. Temporal and spatial resolution is improving constantly. Today, the complete heart can be depicted in a short breath-hold time of about 10 s, compared to 35 to 40 seconds breath-hold time on an older 4SCT system. This results in a considerable reduction of motion artifacts, and enables reduction of contrast material to be used. About 80 cc of contrast are sufficient for an adequate opacification of the coronary arteries. Additional advantages of this shorter scan time and the shorter contrast bolus is less venous contrast enhancement. The latest generation of 64-slice CT scanners offer a spatial resolution of up to 0.5 mm isotropic voxel size, providing a temporal resolution of about 150 to 200 ms. The scan is performed in about 10 s breath-hold time, with a moderate amount of contrast agent of about 80 cc. First clinical studies on the use of 64SCT for the detection of significant CAD (i.e., stenoses >50%) have reported on sensitivities ranging from 86 to 100% and specificities between 95 and 99% for the detection of significant coronary artery stenoses, maintaining high negative predictive values of 98-99% (9-13).
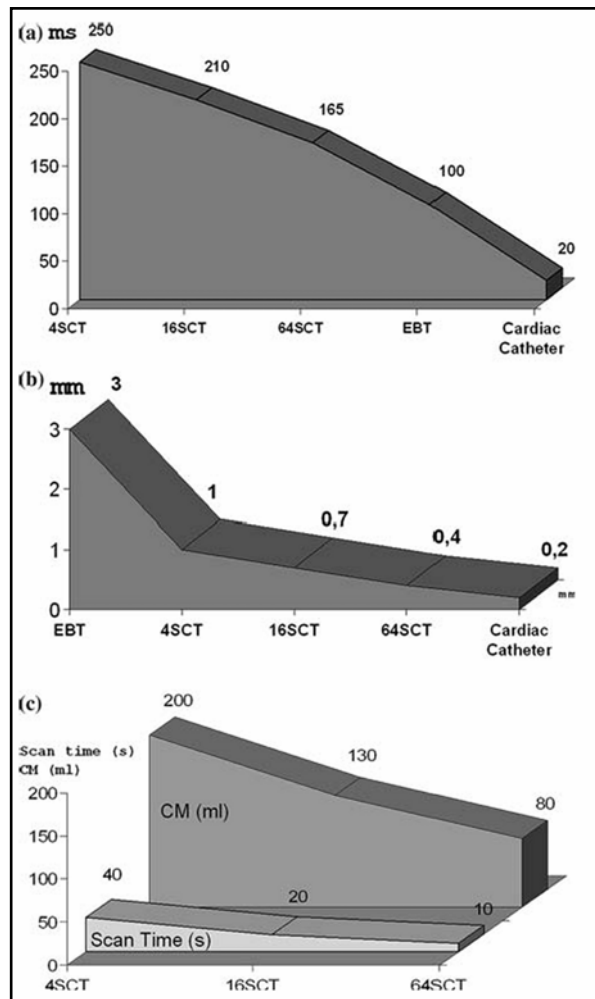
Figure 1: (a) Increase of temporal resolution with various generations of MSCT scanners in comparison to EBT and Cardiac Catheter. (b) Increase of spatial resolution with various generations of MSCT scanners in comparison to EBT and Cardiac Catheter (MSCT = Multi-slice Computed Tomography, EBT = Electron-Beam Computed Tomography). (c) In cardiac CT, a significant reduction of scan time can be observed with increasing detector rows of the CT systems. With the latest 64-slice CT scanners, a contrast-enhanced CT of the heart can be performed in about 10 s breath-hold time. At the same time, the amount of contrast media (CM) can be reduced significantly.
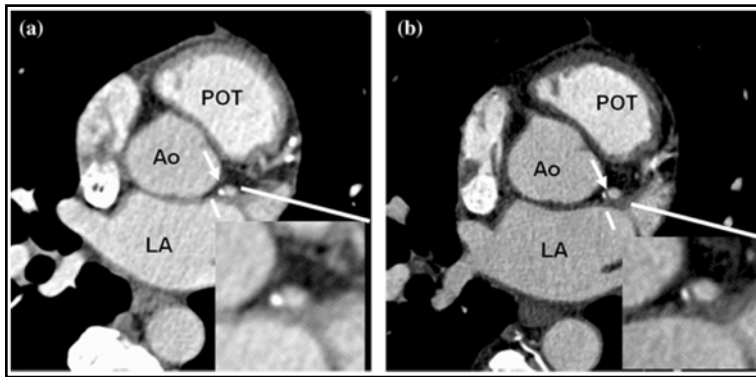
Figure 2: Comparison of plaque imaging: in four-slice CT (4SCT) and 64-slice CT (64SCT). In the 4SCT image (a), composition of the plaque in the proximal left circumflex coronary artery (RCX) is hardly visible due to beam hardening artefacts caused by the calcification and due to limitations in spatial resolution (a, arrow). The same patient underwent 64-slice CT scanning of the coronary arteries (b). Here, plaque composition is sharply delineated, showing the contrast enhanced lumen, as well as calcified and non-calcified

The sensitivity of these systems on a per-patient based analysis range 92 to 100%. These are indeed promising results, especially if the per-patient based analysis is considered as the clinically more important tool than the segment-based analysis. At the same time, the number of studies that cannot be interpreted because of poor image quality has been low (0%–10%), indicating the robustness of this technique. Despite these good results of non-invasive 64SCT coronary angiography, there are still certain limitations to the technique. Primarily because of the limited spatial resolution of MDCT (15 line pairs/cm) compared to selective coronary angiography (50 line pairs/cm), the definitive quantitation of coronary stenoses remains problematic, even if a moderate to good correlation between coronary 64SCTA and intravascular ultrasound could be shown (9). In addition, MSCT coronary angiography is not reliable in patients with significant arrhythmias, fast heart rates, or heavily calcified vessels. Severe calcifications still cause partial volume and beam-hardening artifacts, despite the improvements in spatial resolution in 64SCT. In vessel segments with extensive calcifications, significant coronary artery stenoses can neither be detected nor ruled out. Furthermore, false-positive findings can occur in small caliber vessels. Also, the radiation exposure with a dedicated coronary CTA protocol using 64-slice CT ranges between 8-10 mSv, even if ECG dose modulation is used (8). **Figure 1** shows the development of CT generations over time, depicting improvements in temporal and spatial resolution, at the same time reducing the acquisition times and the amount of contrast required for full vessel opacification. **Figure 2** gives a comparison of two cardiac scans of the same patient, performed on a 4SCT and 64SCT system.

Coronary MR Angiography

Despite the ease and robustness of modern coronary MSCT angiography, Magnetic Resonance Coronary Angiography (MRCA) offers several advantages for coronary imaging. MR does not use ionizing radiation and does not necessarily require the injection of a contrast agent (e.g., using non-contrast-enhanced, time-of-flight technique). Several MR techniques have been proposed for the detection of coronary stenosis with MR, and further development is ongoing. Still, the initial sensitivities and specificities reported in the first work on coronary MRA more than 12 years ago, ranging above 90% (14), could not be reproduced on a regular basis in the following years.
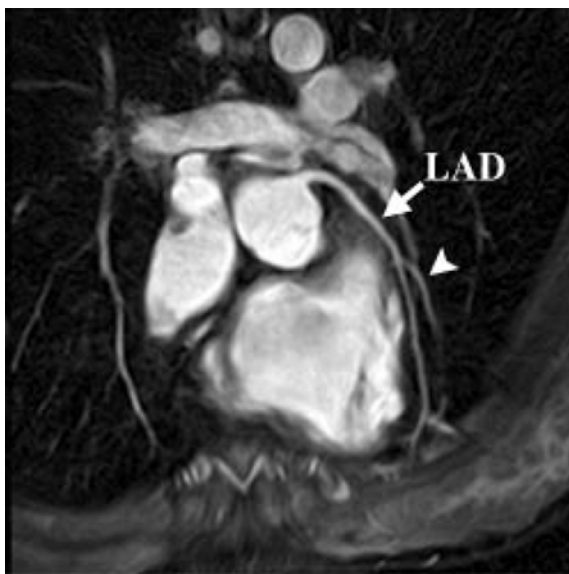

Figure 3. Double-oblique coronal multiplanar reformatted image of the left anterior descending coronary artery (*LAD*) obtained in a healthy adult subject, with T2-weighted navigator-gated free-breathing 3D SSFP coronary MR angiography by using radial k-space sampling.

Modified from (1)*, with permission*

A recent meta-analysis (15), identifying all studies (MEDLINE and EMBASE) that evaluated CAD by both MRCA and conventional angiography in >/=10 subjects during the period 1991 to January 2004, analysed diagnostic accuracy segment, vessel, and subject level. Overall, 39 studies were included, with data on 4,620 segments (993 subjects). Sensitivity and specificity for detection of CAD were 73% and 86%, respectively. Vessel-level analyses (16 studies, 2,041 vessels) showed sensitivity 75% and specificity 85%. Subject-level analyses (13 studies, 607 subjects) showed sensitivity 88% and specificity 56%. The authors of this meta-analysis concluded, that in evaluable segments of the native coronary arteries, CMRA has moderately high sensitivity for detecting significant proximal stenoses and may have value for exclusion of significant multivessel CAD in selected subjects considered for diagnostic catheterization.

In contrast to coronary MSCTA, enabling coverage of the whole heart in just a few seconds, so far, using MRCA, full coverage of the coronary arteries within a reasonable amount of time could hardly be achieved. However, a recent study has

reported on a Whole-Heart 3D acquisition technique (7), using a steady-state free precession sequence with free breathing. In this study, MR angiography was successfully completed in 34 of 39 patients (87%); the average imaging time was 13.8 minutes +/- 3.8 and the sensitivity and specificity of MR angiography for detecting significant stenosis were 82% (14 of 17 arteries) and 91% (39 of 43 arteries), respectively. Other future developments in the area of coronary MR angiography include higher field strengths (3T) (16) and improved contrast techniques, such as balanced steady state free precession techniques (17), radial imaging techniques (18), and improved navigator-gating enabling free breathing of the subject during examination (3). Finally, new intravascular contrast agents may provide the long-awaited boost for reliable magnetic resonance coronary angiography. Initial studies in subjects using such kind of substances have shown promising results (19).

Conclusion – possible clinical role of MSCTA and MRCA

In conclusion, the main advantage of MSCTA over MRCA is the robustness, the ease to use, and the high reproducibility. This robustness is explained by the short breath-hold times, as well as the high temporal and spatial. Still, MSCT will not soon equal the versatility or quantitative accuracy of catheter-based imaging techniques, but it may allow for non-invasive detection and exclusion of coronary obstructions, especially on a per-patient basis. Both MRCA and MSCTA can reliably be used in the detection of coronary artery anomalies, and for the depiction of coronary artery bypass grafts. Still, both MRCA and MSCTA currently seem not suited for the assessment of disease progression in patients with typical angina or unequivocally demonstrated myocardial ischemia on exercise testing or following percutaneous coronary intervention. Patients with high pre-test probability of having significant CAD are still best served by conventional coronary angiography. On the other hand, in recent coronary MSCT studies published, the negative predictive value for MSCTA compared to coronary catheter was in the range between 98 and 99%. Based on these data and limitations, the current use of non-invasive MR or CT angiography should focus on the exclusion of significant coronary disease in patients without a history of significant CAD and a low to intermediate pre-test probability (20). MRA might especially be promising, if coronary angiography and stress perfusion or stress functional imaging of the myocardium could be combined (21). Other potential

indications for MSCTA could be pre-interventional planning, e.g., before stent placement, assessing the true extend of the atherosclerotic coronary artery wall changes in the area of interest, or before biventricular pacemaker placement and atrial fibrillation ablation. In conclusion, the primary goal is the correct selection of suitable patient groups, to potentially reduce the number of unnecessary invasive catheter-based coronary angiographies in the future.

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